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The Effect of Different Abutment Materials on the Alveolar Bone Loss of Implant Supports Restoration. A Systematic Review & Metal Analysis

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Abstract:
Objectives: *The objective of this systematic review was to identify and compare the effect of different abutment materials on the alveolar bone loss of implant supported superstructure.*
Methods*: An electronic Medline search complemented by manual searching was conducted to identify randomized-controlled clinical trials, and cohort studies providing information on ceramic and metal abutments with a mean follow-up time of at least 6months. Patients had to have been examined clinically at the follow-up visit. Pocket depth, amount of rescission and crestal bone loss were attributed to alveolar bone loss.*
Results:*thirteen clinical studies were selected from an initial yield of 107 titles and data were extracted. Pocket probing depth was recorded in seven studies,at 3-year follow-up, PPD around Zr abutments remained 3.2 mm vs. 3.4 mm at Ti sites. Five studies examined the recession index around Zr and Ti abutments. Reporting mean values from 0 to 0.3 at Zr abutments and 0 to 0.4 at Ti abutments. Mean marginal bone loss around Zr abutments was reported to vary from 0.2-0.4mm to 1.05-1.48mm and 0.3-0.5mm to 0.67-1.43mm at Ti abutments.*
Conclusion*: The information included in this review did not provide evidence for differences of the biological outcomes of ceramic and metal abutments. However, it can be concluded that the direct comparison in the same patient does not give a clear preference for the use of zirconia or titanium as abutment materials in relation to alveolar bone response. A meta-analysis showed statistically significant superiority of Zr abutments over Ti abutments in developing favorable response of Marginal Bone Loss, but with non- statistically significant regarding Pocket Probing Depth (PPD) and Recession Index of soft tissue (RI)*
Keywords*: Implant abutments, pocket depth, recession, crestal bone loss,titanium, zirconia*

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I. Introduction

Implant-based rehabilitations are currently a predictable method, which, in some cases is preferred to more classical alternatives such as removable or fixed, tooth-borne prostheses (Vogel et al. 2013). As an substitute ceramic abutmentmade from the high-strength ceramicsalumina and zirconia can be used in estheticallydemanding situations (Payer et al. 2015). The esthetic benefit of ceramicabutments over metal abutments hasbeen well documented in a recent clinicalstudy (Jung et al. 2008). The shortcomingof ceramic materials, however, is theirbrittleness (Belser et al. 2004). This specificmaterial property of ceramic leads toless resistance toward tensile forces andmicro-structural defects. High tensile forces or flaws within the ceramic increase the risk for a fracture during function.Whether a fracture will occur is predominately influenced by the fracturetoughness of the ceramic (Anders et al. 2011).Among all dental ceramics zirconia exhibits the highest fracture toughness (Payer et al. 2015). Clinical studies indicatethat reconstructions can be fabricated with zirconia frameworks either on teethor on implants with good clinical success. No zirconia abutment fractures have beenreported in studies of implant singlecrowns in anterior and premolar regionsduring a maximum of 4 years of function (Glauser et al. 2004; Canullo 2007).In contrast, at 1 year 7% fractures of alumina abutments have been reportedwhen applied in the same type of indications (Andersson et al. 2001). The promisingperformance of zirconia is supported by studies with zirconia as framework materialfor tooth-borne reconstructions even in areas with high loading. A small degree of radiographically determined peri-implant alveolar bone loss. which is defined as a localized lesion involving bone loss around an osseointegrated implant

(Park et al.2007). Numerous studies published in the last 16 years (2000–2017) looked at the success and survival rates of dental implants after at least 10 years of functional loading and found that the mean survival rate ranged from 89% to 95%.8–13. Despite the high long-term survival rates, dental implants are plagued with biological and mechanical complications. (Lopset al. 2013). Crestal bone loss can be caused by mechanical or biological factors. Occlusal overloading is a common mechanical complication that results from an interplay of several factors including poor prosthetic design, inadequate number, dimensions and distribution of implant fixtures, non-ideal implant positions, and parafunctional habits of patients (Zembic et al. 2013). The clinical consequences of which are fractures of implant fixture, abutment screws, prostheses and their attachments and acrylic resin or ceramic veneers, prosthesis or abutment screw loosening, early or late implant failure, and periimplant marginal bone loss. Similar to periodontitis, microbial pathogens in dental plaque is the main biological cause of crestal bone loss (de Alboroz et al. 2014)

Focused question

The key research question of this review was to define the effect of different abutment (all ceramic and metallic) materials on alveolar bone loss. Pocket probing depth (PPD), soft tissue recession (REC) and marginal bone level (MBL) were attributed to the alveolar bone loss

II. Methods

2.1 Criteria for considering studies for this review

2.1.1 Types of studies

All randomized controlled trials (RCTs) & cohort study evaluating the effect of different types of implant abutment (metallic or all ceramic abutment) on the alveolar bone loss of implant supported superstructure.

2.1.2 Types of participants

People who have at least one dental implant affected by bone loss.

2.1.3 Types of interventions

All types of implant abutment (metallic or all ceramic abutments)

2.1.4 Outcomes

Alveolar bone loss, signs attributing for alveolar bone loss

- Radiographic marginal bone level change on intraoral radiographs taken with a parallel technique.
- Probing pocket depth (PPD) change.
- Marginal soft tissue recession (REC) change.

2.2 Search methods for identification of studies

Electronic databases searches

The following inclusion criteria (table1) were imposed: original studies, clinical studies with 6 months of follow-up, intervention recording alveolar bone loss and periimplant inflammatory parameters around dental implants and articles published only in English. Letters to the editor, historic reviews, commentaries, experimental (animal) studies, case-reports, and unpublished articles were excluded (table 2). In order to identify studies relevant to the focused question, the MEDLINE database, the Cochrane Central Register of Controlled Trials (CENTRAL) and Google-Scholar databases were electronically searched. Databases were searched for articles from 2000 through September 2017 with the following Medical Subject Headings (MeSH) terms: (1) dental implantation abutment, (2) dental implants abutment, (3) zirconium abutment, (4) All ceramic abutment ,(5) metallic abutment,(6)titanium abutment (7) periodontal attachment loss, (8) periodontal pocket, (9) periodontal index, (10)alveolar bone loss ,(11) rescission and the combinations . Other relevant non-MeSH keywords were used in the search process to identify articles discussing periodontal inflammatory parameters around different abutment materials. These included "yttriastabilized zirconia implants," "zirconia," "inflammation," "bleeding index" and "bleeding on probing," and "periimplant pocket" and "clinical attachment loss." The titles and abstracts of studies identified with the described protocol were screened by 3 authors (M.M., J.E., O.E.) and checked for agreement. The full texts of those studies judged by title and abstract to be relevant were read by authors (M.M., M.S, J.E.) and independently evaluated in accordance with the eligibility criteria. An additional hand search was performed in the reference lists of all full texts of all studies identified during the initial search. The tables of contents of Journal of Prosthetic Dentistry, Implant Dentistry, Clinical Oral Implant Research, Clinical Implant Dentistry and Related Research, Journal of Clinical Periodontology, and the European Journal of Oral Implantology were independently hand searched by 2 authors (M.M.,J.E.) for relevant studies published up to July 2017. This was done to identify any studies missed in the previous step. The identified studies were then checked for disagreement after discussion among the authors.

Table (1) Inclusion criteria

Inclusion criteria
• Clinical studies with direct comparison of Ti to Zr abutments in the same patient,
• Studies with at least 10 patients,
• Studies with a mean follow-up of at least 6 months
• Studies reporting on at least one of the outcome measures.
• Studies in English

Table (2) Exclusion criteria

Exclusion criteria
Prospective uncontrolled clinical studies
retrospective clinical studies,
RCTs with teeth as control
systematic reviews
experimental (animal) studies
case-reports
unpublished articles

2.3 Data collection and analysis

2.3.1 Study selection

The 107 articles (titles and abstracts) of all reports identified through the electronic searches were scanned independently by two review authors(M.M., J.E.). For studies appearing to meet the inclusion criteria, or for which there were insufficient data in the title and abstract tomake a clear decision, the full report was obtained. The full reports obtained from all the electronic and other methods of searching were assessed independently by two review authors(M.M.,O.E.) to establish whether the studies met the inclusion criteria or not. Disagreements were resolved by discussion. Where resolution was not possible, a third review author (M.S) was consulted. 13 studies meet the inclusion criteria then underwent validity assessment and data extraction. Studies rejected at this or subsequent stages were recorded in the table of excluded studies, and reasons for exclusion recorded (table 3).

2.3.2 Data extraction

Fourteen studies undergo data extraction by two review authors(M.M.,J.E.) independently using specially designed data extraction forms.The data extraction forms were piloted on several papers and modified as required before use. Any disagreement was discussed and a third review author(M.S.) consulted where necessary. All authors were contacted for clarification or missing information. Data were excluded until further clarification was available if agreement could not be reached.

For each trial, the following data were recorded (table 4).

- Year of publication, country of origin and source of study funding.
- Details of the participants including demographic characteristics.
- Details on the type of intervention.
- Details of the outcomes reported, including method of assessment and time intervals.

2.3.3 Dealing with missing data

Attempts were made to retrieve missing data from authors of trials. Change data were used and if only cross-sectional data were available the standard deviation (SD) of the change was to be estimated assuming no within patient correlation, which would give rise to a conservative estimate of the SD for change. The techniques described by Follmann (Follmann 1992) were to be used to estimate the standard error of the difference for splitmouth studies, where the appropriate data were not presented and could not be obtained.

2.3.4 Assessment of heterogeneity

The significance of any discrepancies in the estimates of the treatment effects from the different trials was to be assessed by means of Cochran’s test for heterogeneity and heterogeneity would have been considered significant if $P < 0.1$. The I2 statistic, which describes the percentage total variation across studies that is due to heterogeneity rather than chance, was to be used to quantify heterogeneity with I2 over 50% being considered moderate to high heterogeneity.

Figure (1): Overview of the search strategy.

Table (3): Studies excluded from this review

Author /year	Reason for exclusion
Belser et al. 2004	Review article
Bragger et al.2005	Titanium abutment only
Buchi et al. 2014	Zirconia abutment only
Canullo et al.2007	Zirconia abutment only
De boever et al 2006	Titanium abutment only
Ekfeldt et al.2011	Zirconia abutment only
Glauser et al. 2004	Zirconia abutment only
Muche et al.2003	Titanium abutment only
Nakamura et al. 2010	Zirconia abutment only
Passos et al.2014	Zirconia abutment only
Pjetursson, et al 2004	Systematic review
Sailer et al. 2009	Systematic review
Vigolo et al. 2006	Metallic abutment only
van Brakel et al. (2011)	3-month follow-up
van Brakel et al. (2014)	3-month follow-up
Zembic et al. (2014a)	Teeth as control group

Table (4): Marginal bone levels in included studies

Study	year	Study design	No.of patient	Follow up	Total no. of abutment	Titanium abutment	All ceramic abutment	''bone loss mean (SD)mm''
Andersson et al.	2001	RCT	15	1y-3y	69	35	34	NA
Andersson et al.	2003	RCT	32	5y	103	50	53	0.3 (0.2)mm ceramic and 0.4 (0.3)mm titanium
Zembic et al.	2009	RCT	22	3y	28	10	18	NA
Sailer et al	2009	RCT	20	1y	31	12	19	NA
Hosseini et al.	2011	RCT	31	1y	72	34	38	0.08 (0.17) mm ceramic and (0.25)0.1 mm titanium
Zembic et al.	2013	RCT	18	5y	28	10	18	0.5 (0.5) mm ceramic and 0.8(0.7) mm titanium
Hosseini et al.	2013	CCT	59	3y	73	21	52	0.15 (0.25) mm ceramic and 0.18(0.29) mm titanium
Lops et al.	2013	CCT	81	5y	81	45	36	0.4(0.1) mm ceramic and 0.5(0.1) mm titanium
de Alboroz et al.	2014	CCT	25	1y	25	14	11	0.06 (0.07) mm ceramic and 0.45(0.02)mm titanium
Lops et al.	2015	PCT	72	2y	72	39	33	0.1 (0.1) mm ceramic and 0.3(0.2)mm titanium
Payer et al.	2015	RCT	30	2Y	30	15	15	0.1 (0.19) mm ceramic and 0.16 (0.24) mm titanium
Nascimento et al.	2016	RCT	20	6m	20	10	10	0.92 (0.36) mm ceramic and 1.25(0.27)mm titanium
Yogesh et al.	2017	RCT	12	1y	12	12	12	0.5 (0.50) mm ceramic and 1.53(0.53)mm titanium

Table(5): The effect of zirconia and titanium on peri-implant tissue

study	Year	Follow up	Total no. of abutment	Titanium abutment	All ceramic abutment	Bone level loss measuring method	recession index		Pocket depth	
							zirconia	**titanium**	zirconia	titanium
Andersson et al.	2001	1y-3y	69	35	34	periapical	0.3	0.4		
Andersson et al.	2003	5y	103	50	53	Periodontal probe				
Zembic et al.	2009	3y	28	10	18	Periapical			3.2 (1)	3.4 (0.5)
Sailer etal	2009	1y	31	12	19	Orthoradial Ro			3.5 (0.7)	3.3 (0.6)
Hosseini et al.	2011	1y	72	34	38	Periapical				
Zembic et al.	2013	5y	28	10	18	Orthoradial Ro	0.1 (1)	0.3 (0.7)	3.3 (0.6)	3.6 (1.1)
Hosseini et al.	2013	3y	73	21	52	periapical				
Lops et al.	2013	5y	81	45	36	Periapical			2.6 (0.5)	2.7 (0.4)
de Alboroz et al.	2014	1y	25	14	11	Periapical	REC 0 (0	0.04 (0.1	2.9 (0.5	3.3 (0.8)
Lops et al.	2014	2y	72	39	33	Periapical	0.1 (0.3)	0.3 (0.4)		
Payer et al.	2015	2Y	30	15	15	Periapical				
Nascimento et al.	2016	6m	RCT	10	**10**	Periodontal probe	0.16 ± 0.42	0.27± 0.60	2.12 ±0.70	2.05± 0.87
Yogesh et al.	2017	1y	RPS	12		periapical			3.29 ±0.50	3.38 ±0.53

III. Results

After application of the inclusion criteria, thirteen studies, All studies reported on customized Ti and Zr abutments, and five study also provided data on stock Zr and Ti abutments (Lops et al. 2014, Andersson et al.2001, Zembic et al.2013,Nascimento et al.2016, Yogesh et al.2017). All included studies reported a well-defined period of follow-up (6months-5 years). The total number of abutments included in the studies were 656 (307 Ti and 349 All ceramic) among the studies.

Meta-analysis

Results of the Effect of different abutments materials on Radiographic Marginal Bone Loss (MBL)

Marginal bone level 13 studies (table 3) reported on interproximal marginal bone-level changes. The bone loss was reported as absolute values and as the change. Mean marginal bone loss around Zr abutments was reported to vary from 0.2-0.4 mm to 1.05-1.48 mm and 0.3-0.5 mm to 0.67-1.43 mm at Ti abutments. Some of the papers presented separate mesial and distal values of bone loss. The meta-analysis for the ten included studies was performed to assess the same comparisons and outcomes. We use the mean difference for the continuous outcome (MBL) using random effect model in a software program (RevMan 5.3, 2014).

Assessment of heterogeneity

The significance of any discrepancies in the estimates of the treatment effects from the different trials was to be assessed by means of Cochran's test for heterogeneity and heterogeneity would have been considered significant if $P < 0.1$. The I2 statistic, which describes the percentage total variation across studies that is due to heterogeneity rather than chance, was to be used to quantify heterogeneity with I2 over 50% being considered moderate to high heterogeneity.

All 10 included studies results were pooled using the random model effect as statistical heterogeneity among studies was significance where (I2 = 93% $P < 0.00001$). The mean difference of MBL which used in this meta-analysis as an outcome measure for marginal bone loss between all ceramic and titanium abutments for all pooled results were -0.20 (−0.32-0.08) with 95% confidence interval. This overall estimate is statistically significant with $P < 0.0009$. The meta-analysis was made with random effect model for the continuous outcome (MBL) as seen in (Figure2).

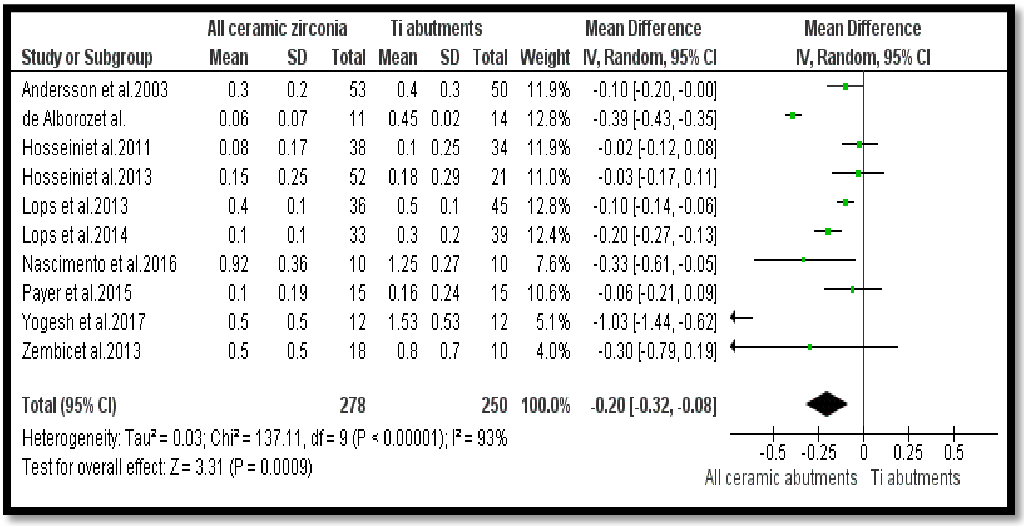

Figure2: Forest plot of comparison implants all ceramic zirconiaabutments versus Ti abutments, outcome: Marginal BoneLoss (mm)

Results of the Effect of different abutments materials on Pocket Probing Depth (PPD)

Pocket probing depth was recorded in seven studies. Six papers measured PPD at four sites, while Albornoz et al.2014 used six PPD sites. At 1-year follow-up, the mean PPD around ALL CERAMIC Zr abutments ranged from 2.9 to 3.5 mm, while the mean PPD around Ti abutments was recorded to be exactly 3.3 mm (Sailer et al. 2009a; de Alboroz et al. 2014; Nascimento et al 2016). In addition, an increase of 0.2 mm from baseline to 1-year follow-up around Zr abutments was recorded, while PPD around Ti abutments remained unchanged (de Alboroz et al. 2014). Recently the mean PPD around Zr abutments was 3.38mm, while the mean PPD around Ti abutments was recorded to be exactly 3.3 mm(Yogesh et al2017) .At 3-year follow-up, PPD around Zr abutments remained 3.2 mm vs. 3.4 mm at Ti sites (Zembic et al. 2009). Results after 5 years of service were provided by two studies. Zembic et al. (2013) showed a mean PPD around Zr abutments of 3.3 mm with an increase of 0.4 mm from the baseline, while Ti abutments had 3.6 mm with an increase of 0.5 mm from the baseline. Lops et al. (2013) reported 2.6 mm at Zr abutments and 2.7 mm at Ti sites. All included studies reported no significant differences between Zr and Ti abutments. The mean difference of PPD which used in this meta-analysiswere -0.10 (-0.25-0.05) with 95% confidence interval. This overall estimate is statistically non-significant with P = 0.18. The meta-analysis was made with random effect model for the continuous outcome (PPD) as seen in**Fig 5**

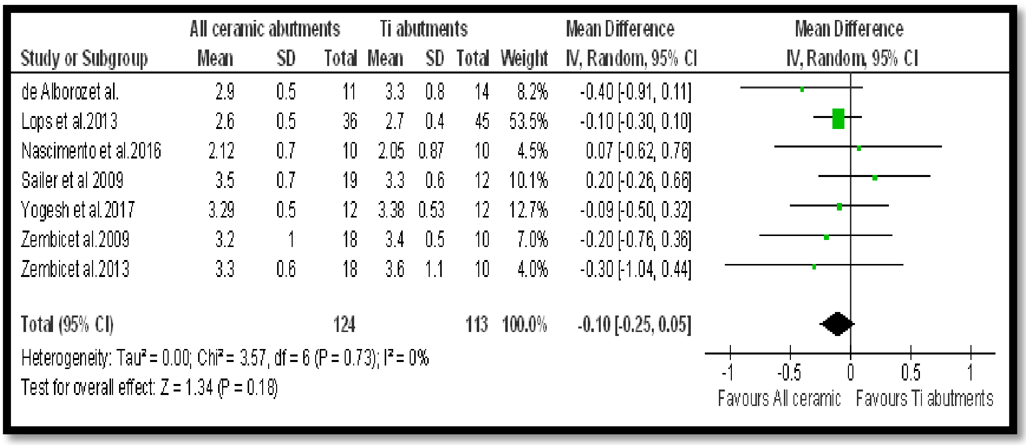

Figure5: Forest plot of comparison implants all ceramic zirconiaabutments versus Ti abutments, outcome: Pocket Probing Depth (mm)

Results of the Effect of different abutments materials on rescission index

Four studies examined the rescission index around Zr and Ti abutments. Reporting mean values from 0 to 0.3 at Zr abutments and 0 to 0.4 at Ti abutments, after 6months the mean of recession index around Zr abutment was 0.16 while for titanium abutment was 0.27 (Nascimento et al.2016).subsequently 1 year follow up the mean of recession index around Zr abutment was zero while for titanium abutment was 0.04 (de Alboroz et al. 2014) , in addition the recession increase after 2 year follow up for Zr to range from 0.3 and was 0.4 for tit abutment (Lops et al.2014),furthermore after 3y and 5y follow up the mean of recession index around Zr abutment ranged from 0.1-0.3 while for titanium abutment was rom 0.3- 0.4(Andersson et al.2001, Zembic et al.2013) with no significant differences between them . The mean difference of rescission indexwas -0.09 (-0.20-0.03) with 95% confidence interval. This overall estimate is statistically non-significant with P = 0.13. The meta-analysis was made with random effect model for the continuous outcome rescission index as seen in**Fig 6**

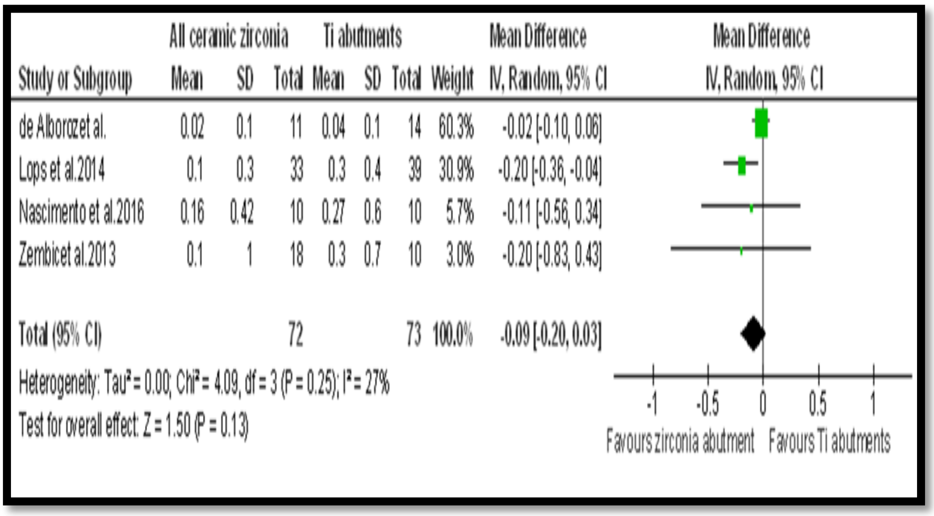

Figure6: Forest plot of comparison implants all ceramic zirconiaabutments versus Ti abutments, outcome: Recession Index (mm)

IV. Discussion

The aim of this review was to thoroughly evaluate the influence of zirconium and titanium abutments on the condition of the alveolar bone loss. The researchers focused on biology in their analysis(pocket depth and recession). The authors decided to exclude studies in which both types of abutments were not compared to each other in one and the same patient. As a result, some well-made prospective clinical studies with the follow-up from 4 to 11 years were omitted (Glauser et al. 2004, Zembic et al. 2014). This choice can be argued; however, uncontrolled prospective clinical trials harbor unavoidable patient bias. Therefore, the longest follow-up studies included into this review were 5 years long (Zembic et al. 2013; Lops et al. 2014). In general, the results have confirmed only minor statistically significant differences between both abutment materials. A similar decision was drawn in a preceding evidence-based review, which evaluated the effect of both abutment materials on crestal bone stability (Linkevicius & Apse 2008). It was stated that based on visceral, human histological and clinical studies, abutments materials (zirconia & titanium) showed no difference in effect on alveoloar bone levels. This present systematic review shows no significant differences in outcome of different abutment materials on pocket probing depths. However, it is interesting to note that one of the excluded studies (due to a short 3-month observation period) by van Brakel et al. (2011) showed significantly lower PPD around Zirconia abutments, compared to Titanium abutment. This study provided detailed picture of the surface roughness of both types of abutments materials (Ra-values 210 Zr–236 Ti nm). New in vitro studies have shown that the surface roughness of the material is very significant in the performance of cells on Zr or Ti. It was found that polished Zr surfaces provide better adhesion for epithelial cells, compared to Ti (Nothdurft et al. 2014). It could be speculated that well adherence of the cells to the abutments might decrease PPD around implants. Theimpact of abutment material on plaque accumulation could be better assessed if titanium or zirconium would be exposed to oral cavity. Biological complications were not frequent in the included studies. The most robust number of biological incidents was recorded in two studies (Hosseini et al. 2011, 2013). Interestingly, the highest amount of biological complications was fistulas, which are usuallytriggered by excess cement (Gapski et al. 2008; Wilson 2009). The design of the abutments explains this finding., The crown margins were located 1–1.5 mm subgingivally. Implant supported Restorations on Zirconia abutments were cemented with resin cement. It can be speculated that biological complications were due to cement remnants. It has been shown that subgingival margins 1–1.5 mm preclude complete removal of cement remnants even with customized abutments (Linkevicius et al. 2011). In addition, resin cement is hard to remove from abutments (Balasubramaniam GR .2017). Therefore, it is safe to accept that these complications are abutment design and cementation agent dependent, and not related to the abutment material. Hidden cement fragments were recognized as a possible reason for implant loss in one of the included reports (Zembic et al. 2013). The study revealed those all-ceramic crowns were cemented on zirconium abutments with resin cement, whose poor cleansability features have already been stated. Again, the supragingival or epigingival margins of abutments are supported, especially if restorations are to be cemented with resin luting agent. also,(Nascimento et al. 2017)revealed differences regarding microbial diversity and microorganisms counts in oral biofilm associated with titanium or zirconia. Finding that the titanium concentrates morebiofilm mass and higher amounts of microorganisms. Due to roughness which is a major factor favoring themicrobial adhesion on titanium surfaces. On the otherhand, zirconia has been described to have a potentially lowersusceptibility for bacterial adhesion and some studieshave suggested that the free energy surface is more importantin biofilm formation on zirconia surfaces.Supporting to the idea of biomaterial properties play a important role in stress distribution around implant abutment which in sequence affect the alveolar bone loss, Mascarenhas et al.(2017) postulated that higher elastic modulus of superstructure material allowed for a more uniform distribution of stresses within the framework, thus providing a more efficient and reliable load transfer to the implants. This could explain that why the all ceramic restorations could redistribute the stresses more evenly to the implants when compared to the metallic restorations.

V. Conclusions

It can be concluded that the up-to-date research on the direct comparison in the same patient does not give a clear preference for the use of zirconia or titanium as abutment materials in relation to alveolar bone response. A meta-analysis showed statistically significant superiority of Zr abutments over Ti abutments in developing favorable response of alveolar bone

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